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PRELIMINARY RESEARCH ON USING INDUSTRIAL PLANTS IN CONSTRUCTIONS

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Abstract

The research was based on the identification of several products from industrial plants made for the constructions sector and able to satisfy the needs of supporting the farming sector and a sustainable economy. Building friendly environmentally materials today are only possible if the products are based on renewable resources. The natural resources will help the construction industry to reduce the pollution and to be more eco-friendly. Trying to develop new materials the present paper is focus on hemp products. The first part present the raw materials used for the new composite products based on hemp and polyvinyl acetate and the second part of the paper show the results obtain for sound absorption coefficient, reaction to fire and mechanical strengths. The hemp products will have a positive impact on the environment reducing the emission of CO2 and also will help to preserve natural resources.

Key words**:** *hemp, mechanical strengths, polyvinyl acetate, reaction to fire, sound absorption coefficient, sustainable materials*

INTRODUCTION

New trends in research and in the development of materials for the sector of constructions aim at passing on from products based on limited and non-renewable resources to environmentally friendly products, based on renewable raw materials. A large part of the renewable raw materials is vegetal in origin.

Research on the use of natural fibres and of the waste originating from the processing of industrial plants or as reinforcements in composite materials has come to be the basis for the materials used in civil engineering [8].

Among industrial plants, literature presents hemp as totally renewable materials: seeds can be used in food; fibres can be used for textile materials, paper production, vehicle panels and hemp shives for the constructions sector. As hemp cultivation does not require special care, hemp can bring in significant economic benefits [5].

According to the data presented by the Food and Agriculture Organization of United Nations Statistics division, since 2010-2013, in Europe, an increase in the cultivation of hemp is seen at continental level (Fig.1) [3].

An explanation for the increase in hemp production at European level could be the extended research during the recent years regarding hemp plant.

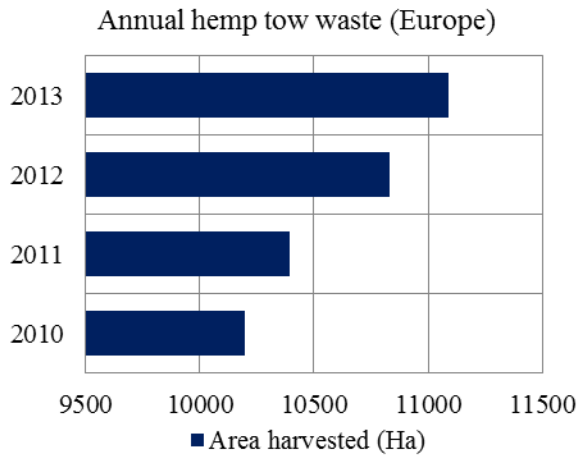

Fig.1. Europe hemp tow waste area
Source: Own interpretation

It is estimated that globally there are over 25,000 products based on hemp, and that now, in over 30 countries, industrial hemp is grown as a raw material for the world market [4].

This study is focused on the use of industrial plants in the production of new building materials in the composition of which lightweight aggregates are also found, such as perlite and/or vermiculite.

MATERIALS AND METHODS

Materials

Hemp is an industrial plant that easily adapts to the growth conditions and has a large variety of species. Its stem contains 20-40% fibers and 60-80% hemp shives or crust. Hemp has the following chemical composition: cellulose (55-72%), hemicellulose (8-19%), lignin (2-5%), wax (<1%) and minerals (4%).
Hemp shives exhibit a larger content of lignin (19-21%) and hemicellulose (31-37%), but a smaller content of cellulose (36-41%) [1].
Polyvinyl acetate is polyvinyl glue, containing 80% water; it is white in color. It behaves well in the context of elements containing a high percentage of water. It has high water solubility and consequently it is more recommended for interior use [2].
Lightweight aggregates, perlite (vermiculite) are lightweight insulating materials, produced by expanding the natural volcanic rock to get a cellular structure [7], at high temperatures. Perlite (Fig.2) is a mixture of silica dioxide SiO_2-75% and aluminum oxide Al_2O_3 -23%.

Fig.2 Lightweight aggregates- Perlite
Source: Own portfolio.

Perlite is regarded as a green material, of high porosity and a density between 150-200 kg/m^3. It is used in thermally insulating mortars and concretes due to its thermal insulation properties; it does not degrade in time, it does not burn at temperatures between -200^{o}C and +850^{o}C [6]. Taken as a good thermal, acoustic and fire insulator, perlite does not pollute the environment; it is catalogued as a form of natural glass, chemically inert and with a pH of approximately 7[9].
Vermiculite (Fig. 3) is a granular material, with the appearance of mica, rich in iron, magnesium and silicate ions. It is utilized as an aggregate in fire resistant mortars, having a density of 110 -130 kg/m^3 and water absorption of 60-70 % of the volume [10].

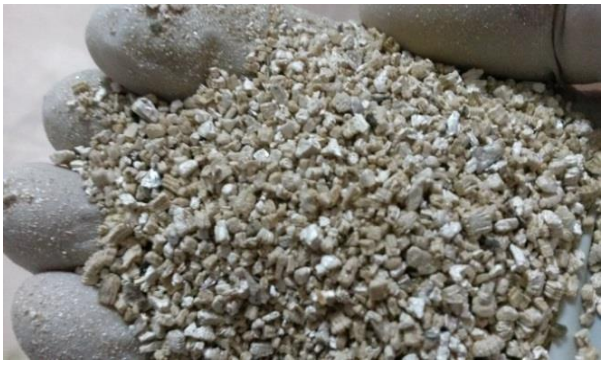

Fig. 3. Lightweight aggregates- Vermiculite
Source: Own portfolio.

Formulae structure

The products under investigation were made from hemp mixed with polyvinyl acetate, to which lightweight aggregates, such as perlite and/or vermiculite were added. Three formulae were obtained, their composition being given in Table 1.

Table 1. Formulae structure

Name	Composition
C_3+P_2	C_3-Hemp 60% P_2- Perlite 40 %
C_3+V_2	C_3-Hemp 60% V_2- Vermiculite 40 %
C_3+PV_2	C_3-Hemp 60% PV_2- Perlite with vermiculite 40 %

Source: Own determination.

In the three formulae, the amounts of hemp and polyvinyl acetate were identical and constant, only the amount of lightweight aggregate was modified. The polyvinyl acetate amount added in the mixtures was in ratio 1:2 hemp - polyvinyl alcohol and 1:4 lightweight aggregate - polyvinyl acetate. The formulae (Fig. 4) were mixed mechanically

with a mixer; the compaction in the work forms was performed manually, with a ram. After 24 hours the products were stripped from the forms.

Fig. 4. Visualization of component materials of the 3 recipes: a. C_3+P_2, b. C_3+V_2, c.C_3+PV_2
Source: Own portfolio.

Determination of physical and mechanical properties

After the three formulae were dried up, samples were tested for acoustic, mechanical properties and fire reaction.

Regarding the acoustic part, the sound absorption coefficient was determined for a frequency range of 0-6,400 Hz, with the help of Kundt tube (Fig. 5.a) and the Pulse software (Fig. 5.b). The equipment belongs to the technical equipment of the Transylvania University of Brasov.

To determine the values of sound absorption coefficient, two circular shape specimens were made, with the diameter of 28 mm and 100 mm, for every specimen.

The curves of the sound absorption coefficient for the frequency ranges 0-1,200 Hz and 500-6,400 Hz were compiled in the Pulse software and a curve with the values of the sound absorption coefficient in the interval 50-6,400Hz was found.

Fig.5. Determination of acoustic absorption coefficient
a. Kundt tube, b. PULSE software.
Source: Own portfolio.

The reaction to fire of the materials was put to test in the laboratory of the Rigips Company from Turda (Fig. 6.a). The test consists in an arrangement of the specimen to fire, at both ends, (Fig. 6.b), at a temperature of 950^{o}C, and then the failure time was recorded.

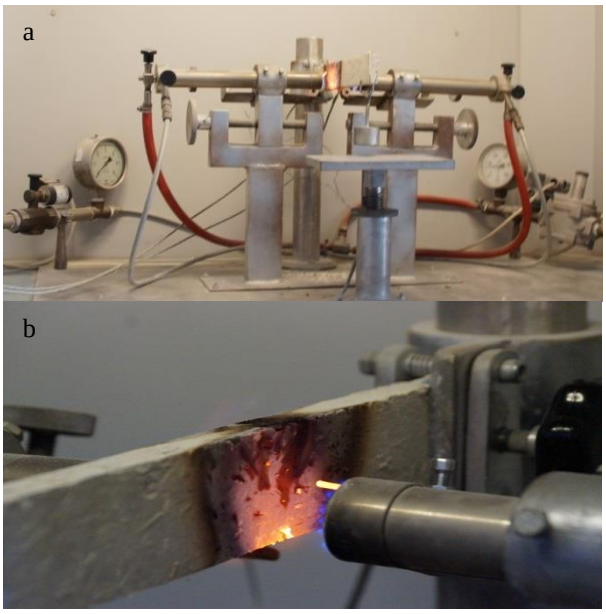

Fig. 6. Reaction to fire determination
a. Equipment
b. Specimen detail
Source: Own portfolio.

From a mechanical point of view, the samples were placed to three tests, where resistance to compression and flexural tensile strength were tested on prisms of 40x40x160 mm, while axial tensile on specimens with breaking section 5cm^2.

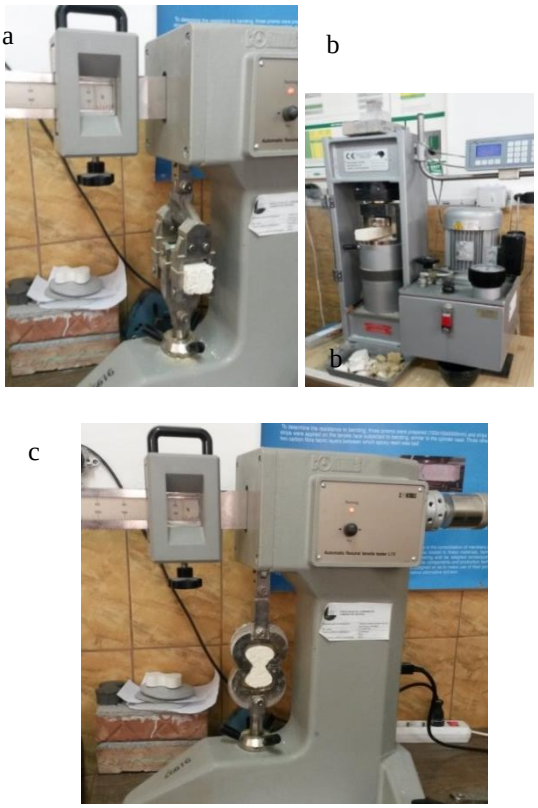

Fig. 7. Determination of mechanical properties
a. Fruhling Michaelis(flexural tensile strength)
b. Hydraulic press
c. Fruhling Michaelis (axial tensile)
Source: Own portfolio.

Compressive resistance was calculated with the hydraulic press (Fig.7.b), flexural tensile strength and axial tensile with the Fruhling Michaelis device (Fig. 7.a,c), from the laboratory of the Faculty of Civil Engineering of the Technical University of Cluj Napoca.

RESULTS AND DISCUSSIONS

Sound absorption coefficients

The values of the sound absorption coefficient for the three formulae (Fig. 8) highlight that the sample with the best behaviour as an sound absorbing material is the formula containing both perlite and vermiculite in the mixture (C_3+PV_2).

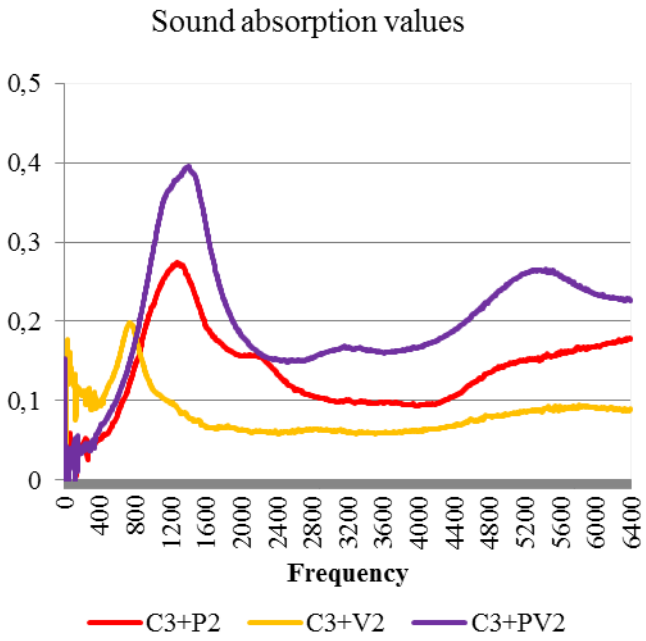

Fig. 8. Sound absorption coefficient values.
Source: Own calculation.

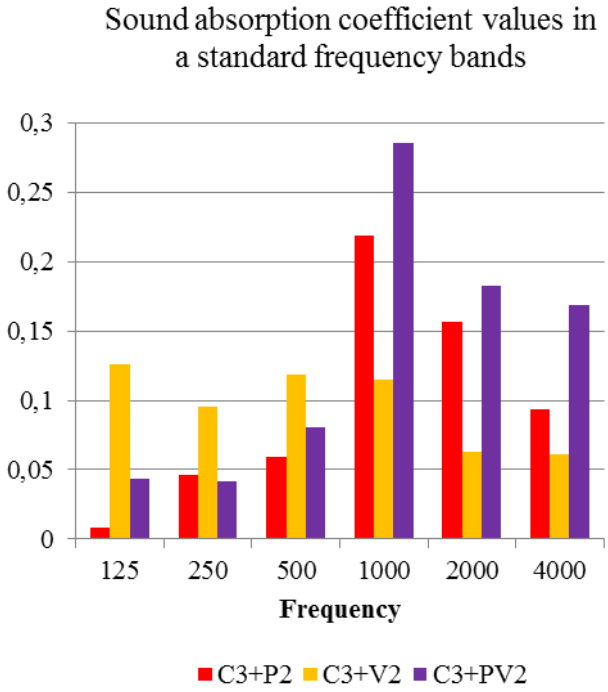

Fig. 9. Sound absorption coefficient values in frequency ranges.
Source: Own calculation.

The mixture of hemp with vermiculite only records the smallest values; so that a first idea that perlite has a positive effect can be forwarded, for the frequency interval 1,000-6,400 Hz, relative to noise protection

materials.

Fig. 9 presents the values of the sound absorption coefficients in frequency ranges. Mention should be made that vermiculite positively influences the values of the sound absorption coefficients in the range 0-500 Hz, after which the effect of perlite and vermiculite is more significant at 100-4,000Hz.

In brief, at the end of the analysis of sound absorption coefficient it is recommended to continue the research on the influence of the perlite and vermiculite amount upon hemp samples, considering that it can become a potential product on the market of sound insulation materials.

Tests of reaction to fire

The study of the reaction to fire of the materials based on hemp and lightweight aggregates is only a starting study, taking into account that both hemp and polyvinyl acetate have low level properties in reaction with fire.

The use of lightweight materials, such as perlite and vermiculite, confers samples a small stability to fire, they resist for several seconds at a temperature exceeding 950 ^{0}C, when volcanic rocks resist normally at temperatures ranging between -200^{o}C and +850^{o}C.

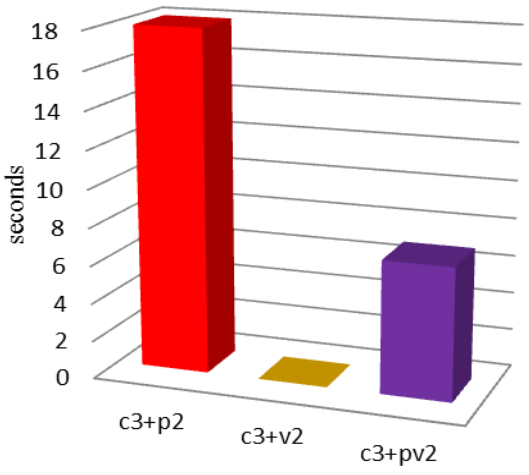

Fig.10. The reaction to fire of the formulae
Source: Own calculation.

In such conditions, it is found that samples containing perlite have a longer reaction to fire compared with the sample made of hemp and vermiculite (Fig. 10).

In further studies, the plan is to continue to study several solutions for fire protection of materials made from hemp and polyvinyl acetate.

Mechanical strengths

The mechanical properties of the three formulae were tested with the hydraulic press and the Fruhling Michaelis equipment, after 28 days from sample casting.

The hemp and polyvinyl acetate based materials present resistance to compression values (Fig. 11) over 2N/mm^2 when perlite is included. On the other side, the vermiculite sample records a value for the compressive strength that is smaller by about one unit than that of the perlite sample.

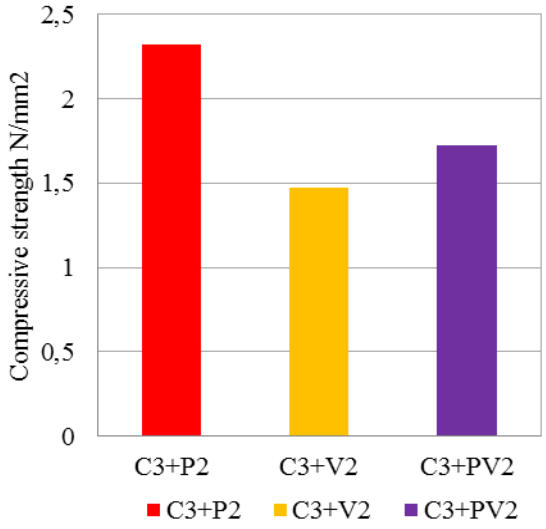

Fig.11. Mechanical strengths -Compressive strength
Source: Own calculation.

In the case of the flexural tensile strength test (Fig. 12), the situation is similar, as the sample made with hemp, perlite and polyvinyl acetate records the highest value (1,5 N/mm^2), compared to the other two formulae. With respect to samples C_3+V_2 and C_3+PV_2, the difference in the values of the bending strength is quite small, the two samples present close values as C_3+PV_2 has about 1,2 N/mm$_2$, while sample C_3+V_2 presents the value of 1,1 N/mm^2.

To axial tensile (Fig.13), sample C_3+PV_2 is the weakest of the three formulae, as sample C_3+V_2 overcomes it, compared to other previous results for the compressive and

flexural tensile strength. Exceeding by little the value of 3,5 N/mm^2, sample C_3+P_2, has the best behaviour to axial tensile test.

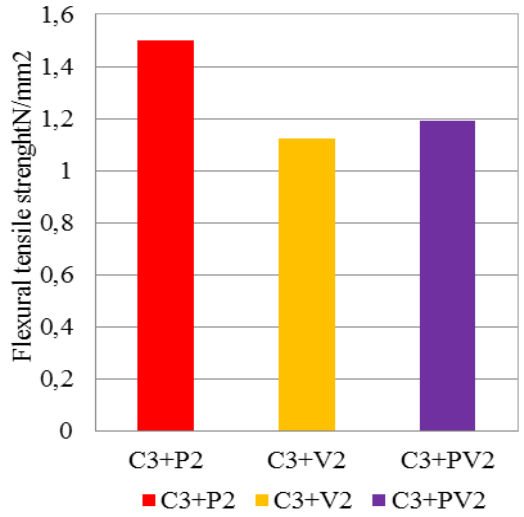

Fig.12. Mechanical strengths -Flexural tensile strength
Source: Own calculation.

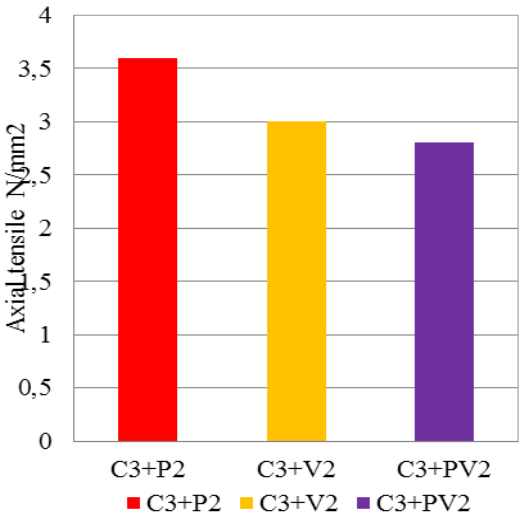

Fig.13. Mechanical strengths - axial tensile strength
Source: Own calculation.

In sum, an analysis of the mechanical properties of the compositions with hemp and polyvinyl acetate plus lightweight aggregates shows that added perlite records best values for the mechanical properties, and suggests that further investigation of the volcanic rock properties mixed with hemp shives should be performed.

CONCLUSIONS

During the three tests, the materials including perlite in the composition recorded the highest values both in the mechanical properties and in their reaction to fire. However, the sound absorption coefficient values are shown to depend upon the mixture of perlite and vermiculite, which can provide a high acoustic absorption.

More in-depth studies related to the resistance to fire and improvement of the acoustic absorption coefficient could lead to a material able to successfully replace materials having synthetic products in their composition. The preliminary research made here highlights that properly developed hemp-based products can become a sustainable alternative in the market of building materials.

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